Medina Watershed, TX
Base Level Engineering (BLE) Results

TWDB Contract No. 1800012224 Task Order 3

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Table of Contents

Executive Summary

Texas Water Development Board (TWDB) contracted AECOM to complete a Base Level Engineering (BLE) viewer deliverable for a BLE analysis that was previously performed for the San Antonio River Authority (River Authority) on the Medina HUC-8 Watershed in Central Texas. This analysis and deliverable supports FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs).

The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory-quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 1.1.

Flood discharges for this study were calculated using both the United States Geological Survey (USGS) regression equations and gage analysis, where stream gages with sufficient record exist. Regression equations were obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009).

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 4.1.0 was used to compute water surface elevations on a stream by stream basis. All hydraulic models were computed using 1-D steady state analysis.

The stream mile network that was validated for these watersheds was compiled using FEMA's Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1 lists the Zone A stream miles associated with this validation analysis.

Table ES-1: Summary of Stream Miles

Source	Medina Stream Miles
CNMS	73.1

Typically, the full inventory of Zone A studies in the watershed would be classified in CNMS; however, CNMS validation checks A1-A5 were not completed for streams that were included in the recent Physical Map Revision (PMR) under FEMA Case No. 19-06-0043S. Total miles validated in CNMS are summarized in Table ES-2 and illustrated in Figure ES-1 below.

Table ES-2: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	2.8
UNVERIFIED	BEING STUDIED	70.3

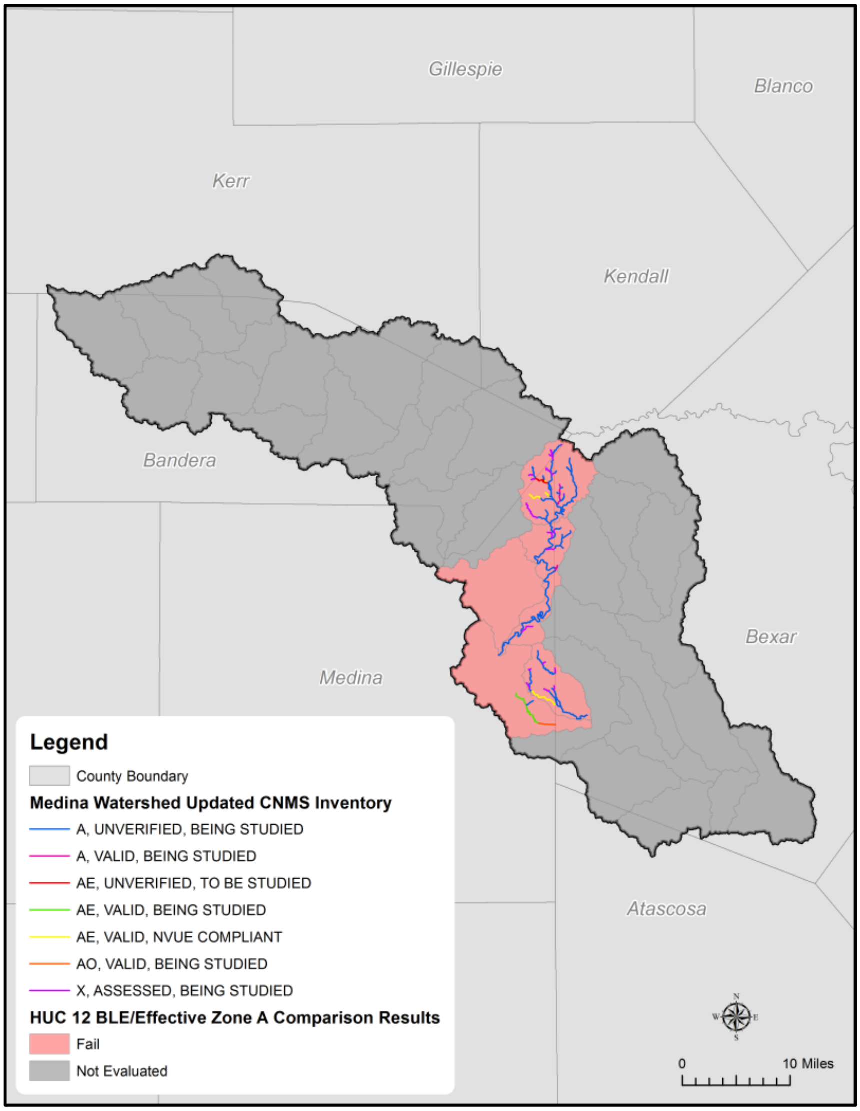

Figure ES-1: Medina Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effective to determine the priority score. Figure ES-2 below shows the range of the Medina HUC-8 priority scores, for those that were evaluated (those not included in recent PMR Case No. 19-06-0043S), which can be used to initiate discussions during the Discovery phase.

Diversion Lake-Medina River HUC-12 was determined to have the highest priority score and the most need while Flat Creek-Medina River HUC-12 had the lowest score.

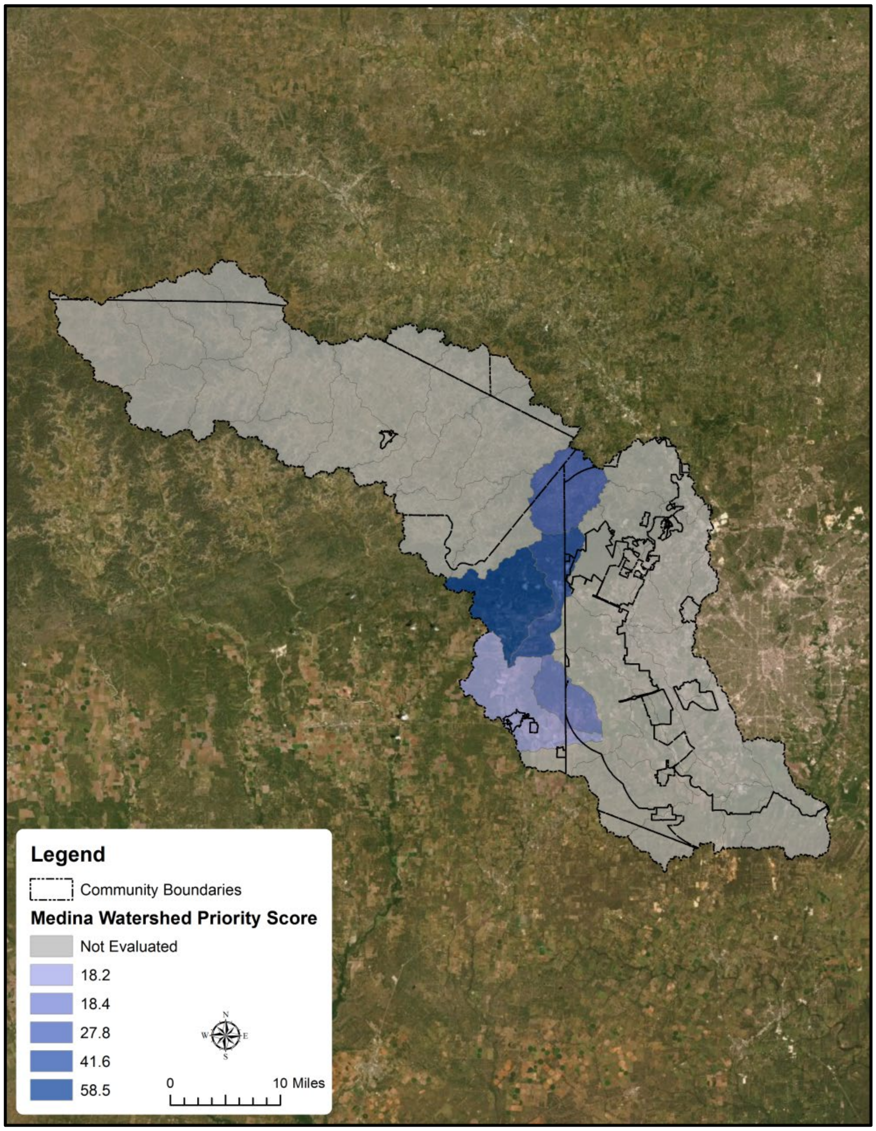

Figure ES-2: Ranking of Medina Watershed HUC-12s

Base Level Engineering (BLE) Methodology

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop a process called Base Level Engineering (BLE), which can be used to address current program challenges, including the validation of Zone A studies and the availability of flood risk data in the early stages of a Flood Risk Project. The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals. The cost for developing the data and estimates resulting from the BLE process are lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood-prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the Coordinated Needs Management Strategy (CNMS) Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH, or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been lacking.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a Flood Risk Project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared and results should be discussed with stakeholders.

An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis can not only be used for CNMS evaluations of Zone A studies, but can also be leveraged throughout the Risk MAP program. The data resulting from a BLE analysis can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

TWDB contracted AECOM to complete a BLE viewer deliverable for the Medina Watershed in Central Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Bandera, Bexar, Kendall, Kerr, and Medina Counties, and include the following communities: the Cities of Bandera and Castroville. The Medina HUC-8 consists of five HUC-10 basins: North Prong Medina River, Upper Medina River, Middle Medina River, Lower Medina River and Leon Creek. This BLE study did not model any streams in the Leon Creek HUC-10 and only modeled streams in the Lower Medina River HUC-10 that are within Medina County. Figure 1 shows the orientation of the Medina HUC-10 basins with respect to the counties.

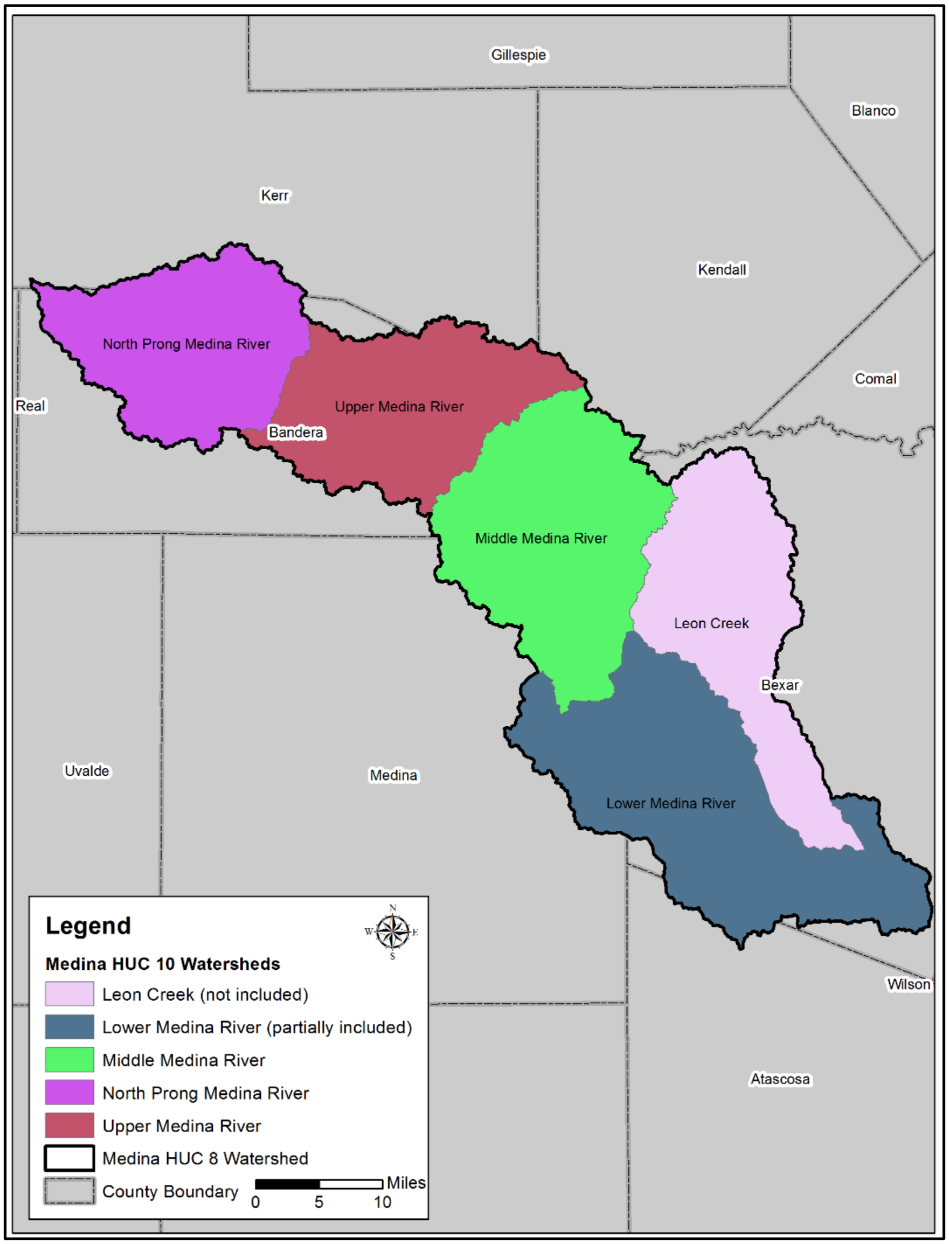

Figure 1: Medina Watershed HUC-10 Basins

AECOM studied approximately 900 miles of stream reaches within the Medina Watershed with a minimum drainage area tolerance of one square mile outside of population centers and half a square mile inside population centers. The selection and extent of stream reaches studied were based upon the number of stream miles with a minimum drainage area of one square mile and not the number of effective Zone A stream miles. Study reaches were extended above this threshold as appropriate to ensure all effective Zone A flood areas received an updated analysis. Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. The following sections summarize the BLE process and discuss the results along with their recommended use.

1.1 Topographic Data

Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. Topographic data were obtained from the Texas Natural Resources Information System (TNRIS), and the United States Geological Survey (USGS).

All available metadata, survey reports, and other leverage documentation are available with the source dataset. Figure 2 shows the extents of the source Digital Terrain Model (DTM) data used for the Medina Watershed.

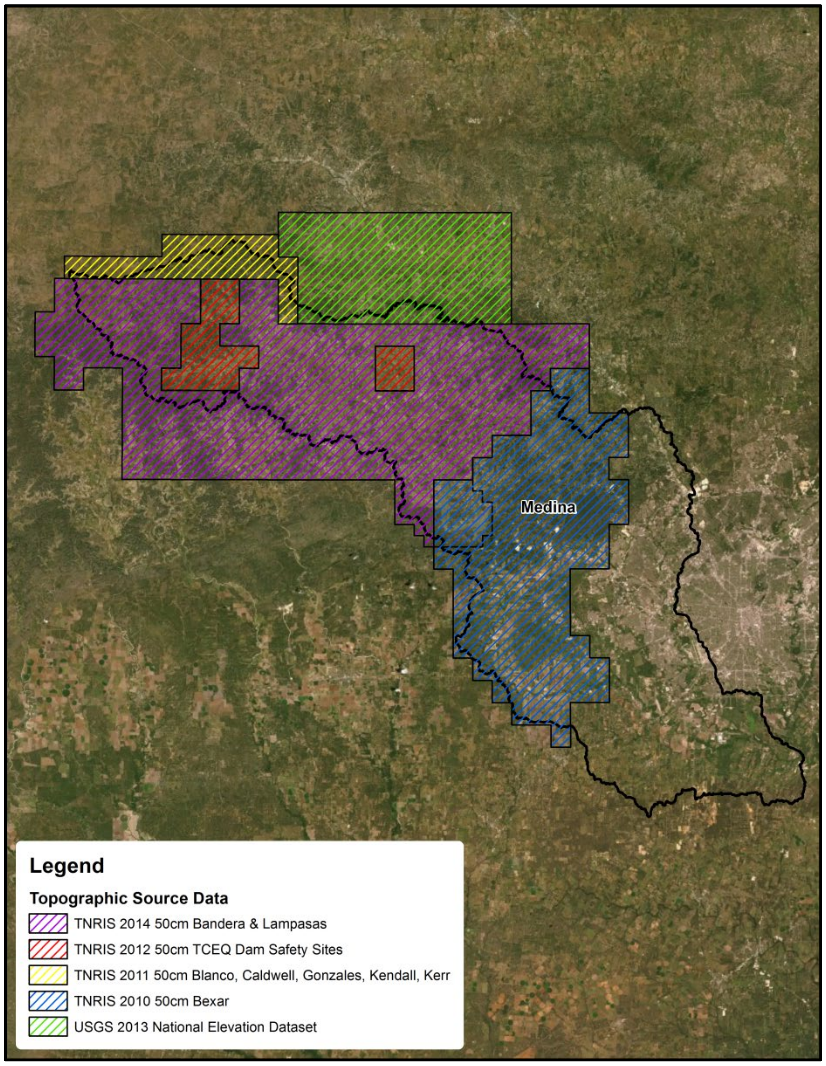

Figure 2: Extent of LiDAR Data for Medina Watershed

1.1.1 Source Terrain Data

Five topographic datasets were used in the development of the BLE hydraulic models. Details on each dataset are outlined below.

1.1.1.1 TNRIS 2014 50cm Bandera & Lampasas

This data has been acquired and developed by TNRIS for collection and delivery of topographic elevation point data derived from multiple return LiDAR measurements for the 2,256 sq. mile project area encompassing Bandera and Lampasas Counties, Texas. Fugro EarthData, Inc. acquired 305 flight lines in 36 lifts from December 18, 2013 to January 25, 2014. LiDAR data collection was performed with a Cessna 310 twin engine aircraft, utilizing a Riegl LMS-Q680i LiDAR sensor; collecting multiple returns x, y, and z as well as intensity data. The classified LiDAR point cloud data are delivered in LAS 1.2 format: 1, unclassified, 2, bare-earth ground, 3, low vegetation, 4, medium vegetation, 5, high vegetation, 6, buildings, 7, low points(noise), 9, water, 13, bridges, and 14, culverts. Specialized in-house and commercial software processes the native LiDAR data into 3-dimensional positions that can be imported into GIS software for visualization and further analysis. The horizontal datum for the data is in UTM 14N Coordinates, NAD83 (2011) in meters and the vertical datum is the North American Vertical Datum of 1988 (NAVD88) in meters using GEIOD12A.

The data acquired will become part of an ongoing data collection by the State of Texas to support mapping and modeling of flood plains, hydrography, and terrain. The data are intended to exceed requirements for FEMA specifications for Floodplain Mapping as well as serve as an input to the U.S. Geological Survey refinements to the National Elevation Dataset. The project consists of high accuracy classified LiDAR data in LAS format as well as raster digital elevation models and intensity images.

This dataset was acquired through the HPIDS contract. The contract was created in 2009 to maximize spending power by coordinating geospatial data purchases to share costs and to ensure that acquired data meet high standards of quality. The successor to HPIDS is the StratMap contract, established in 2015.

1.1.1.2 TNRIS 2012 50cm TCEQ Dam Safety Sites

Topographic mapping of eleven small project sites mapped throughout Central and Eastern Texas in April of 2012. Site A consisted of a total of 40 individual tiles. The product covered by this metadata file consists of classified LiDAR point clouds in .LAS format, collected with a Trimble Harrier 68i LiDAR sensor by SAM, Inc.

The purpose of this LiDAR data is to become part of an ongoing data collection by the State of Texas to support mapping and modeling of flood plains, hydrography, and terrain. The data will also be used by the TCEQ Dam Safety staff in the performance of hydraulic modeling to determine potential areas of inundation downstream of dam structures for inclusion in Emergency Action Plans and to more accurately assess the downstream hazard rating.

This dataset was acquired through the HPIDS contract. The contract was created in 2009 to maximize spending power by coordinating geospatial data purchases to share costs and to ensure that acquired data meet high standards of quality. The successor to HPIDS is the StratMap contract, established in 2015.

1.1.1.3 TNRIS 2011 50cm Blanco, Caldwell, Gonzales, Kendall, Kerr

The project area is 802 DOQQQ tiles covering approximately 3241 square miles in the central region of Texas. The project design of the LiDAR data acquisition was developed to support a nominal post spacing of 4 points per square meter. The dates of acquisition were from February 4, 2011 to March 5, 2011. A Leica ALS50 phase II+ and a Leica ALS60 LiDAR sensor (Gonzales Block) were used collecting multiple return x, y, and z data as well as intensity data. LiDAR data was processed to achieve a bare ground surface.

The purpose of this project is to collect and deliver topographic elevation point data derived from multiple return LiDAR measurements for north region in Texas. The elevation data will be used as base data for Texas flood plain mapping.

This dataset was acquired through the HPIDS contract. The contract was created in 2009 to maximize spending power by coordinating geospatial data purchases to share costs and to ensure that acquired data meet high standards of quality. The successor to HPIDS is the StratMap contract, established in 2015.

1.1.1.4 TNRIS 2010 50cm Bexar

This project contains 50cm LAS tiles and 1m DEM tiles for areas in Bexar County Texas. The project AOI was defined by NQQQ tiles. The outside tiles were buffered by 300m on all sides and the interior tiles were buffered by 50m on all sides. The project design of the LiDAR data acquisition was developed to support a nominal post spacing of 4 points/meter.

Data was acquired by Terrapoint from May 20 through August 4th, 2010. LiDAR data collection was performed with a Cessna 375 aircraft, utilizing a Leica ALS50-II MPiA sensor and a Cessna 210 aircraft, utilizing an Optech Sensor collecting multiple return x, y, and z data as well as intensity data. LiDAR data was processed to achieve a bare ground surface.

This dataset was acquired through the HPIDS contract. The contract was created in 2009 to maximize spending power by coordinating geospatial data purchases to share costs and to ensure that acquired data meet high standards of quality. The successor to HPIDS is the StratMap contract, established in 2015.

1.1.1.5 USGS NED DEM

The National Elevation Dataset (NED), a product of the USGS, is a seamless gridded dataset representing the best available raster elevation data available to the USGS for the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. The NED serves the Medina Watershed topographic data development activity for hydrology needs only and is being used outside the county boundary for calculating contributing drainage area.

1.1.2 Terrain Data Processing

The LiDAR data were processed in Environmental System Research Institute (ESRI) ArcGIS software to create a composite DTM dataset for the project area. The outputs from the processing described below were used during the hydrology, hydraulics, floodplain mapping and CNMS processes and validations.

The Watershed Information System (WISE) software platform was utilized in order to create a digital surface model for the project area. This module allows source data from a variety of sources to be prioritized based on level of accuracy or preference of the user.

For the Medina Watershed, the 2014 Bandera & Lampasas LiDAR was the highest priority, with the 2012 TCEQ Dam Safety Sites LiDAR prioritized second, the 2011 TNRIS Blanco, Caldwell, Gonzales, Kendall, Kerr LiDAR prioritized third, the 2010 Bexar County LiDAR fourth and the USGS NED prioritized fifth. These datasets were used as the data sources for creating the 10-foot and 50-foot DEMs.

The DEMs created from the LiDAR datasets mentioned above were compiled in order of vertical accuracy into a mosaic dataset using ArcGIS. From this mosaic, a tile index was created for the project area and the mosaic was clipped into 50,000-foot tiles, converted to asciis and imported into WISE Terrain Analyst (WTA). Visual inspection of the 10-foot DEMs was performed to ensure no voids and/or artifacts were present in the DEM. The DEM surface model was affirmed to be suitable for hydraulic takeoffs and supporting other hydraulic analyses.

After the DEM was imported, an additional 50-foot DEM was created from the same mosaic and tile index used for the 10-foot DEM. This 50-foot DEM was used for hydro enforcement of the project areas. Proprietary software was used to identify natural sinks, peaks and flat areas in the 50-foot DEM surface. Elevations of the cells in the DEM were algorithmically calculated and the best path to route flow was determined without filling sinks in the DEM. Once all calculations were completed, the flow was checked confirming that all drainage flowed downstream correctly and routed to outside of the project area.

Stream centerlines were manually digitized using the 10-foot DEMs as a source for horizontal alignment and vertical elevation. These stream centerlines are created for use in the hydraulic analysis, hydro-enforcement of the 50-foot DEMs, and visual reference on the FIRM products. Several routines were then used to take localized elevations from the source topographic data and apply them to the stream. This gave the stream vertices elevation information along the Z axis. The resulting elevations ensure that the streams are lower in elevation than any overbank sumps. A separate routine was then used to ensure that the elevations of these vertices descend in height down to an outfall. The final streams file is then “burned” into the 50-foot DEMs to force flow through structures while preventing it from jumping out of the channel banks.

In addition to the quantitative assessment of the source digital terrain, a qualitative visual inspection of the composite DEM was performed using a hillshade derived from the 10-foot DEM. The visual inspection indicated that no unusual or non-terrestrial features were observed in the composite DEM, assuring the surface files used for hydrologic and hydraulic analyses and floodplain mapping activities are sufficient for BLE analysis.

1.2 Hydrology

Flood discharges for this study were calculated using both the USGS regression equations and gage analysis, where stream gages with sufficient record exist. Regression equations obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009) contain the most recent regression equations for Texas. USGS Peak FQ Version 7.1 was used to perform the Flood Frequency Analysis (FFA) for the three gages within the Medina Watershed (see below for further discussion).

1.2.1 Regression Analysis

The WISE computer program was used to delineate drainage basins in shapefile format using the 50-foot resolution DEM. WISE was used to calculate the main-channel slope for each basin. The basin shapefile attribution was automated by WISE with drainage area and main-channel slope. In order to perform the regression analysis and attribute each basin with appropriate discharge values, a script was written in Python and run in ESRI's ArcCatalog. This script required input of drainage area and main-channel slope (from WISE), as well as mean annual precipitation, OmegaEM and the calibration adjustment discussed below.

The annual precipitation values reflect data for the climatological period 1981-2010 as recorded by the Natural Resources Conservation Service (NRCS). The mean annual precipitation values were determined based on a shapefile coverage obtained from the Texas Water Development Board and available for download from the following location: https://www.twdb.texas.gov/mapping/gisdata.asp.

Main-channel slope was calculated in WISE. An automated routine was used to determine the longest flowpath from the upstream of a reach to the outlet of the sub-basin of interest based on flowpaths developed from the 50-foot DEM. Once the length of the flowpath was delineated, elevations for the endpoints were determined based on the TIN developed from the LiDAR. The slope was calculated by dividing the fall by the reach distance and the result was reported in foot/foot.

From USGS SIR 2009-5087, the OmegaEM parameter is a generalized terrain and climate index that expresses relative differences in peak-streamflow potential. A shapefile was developed and populated with OmegaEM values based on Figure 2 in SIR 2009-5087. This shapefile was used, along with a python script in ArcCatalog, to determine OmegaEM values on a sub-basin basis. For streams flowing west to east and crossing the line where the OmegaEM values changes from 0.33 to 0.192, OmegaEM values were modified using area weighting. Otherwise, discharges would decrease significantly as the OmegaEM value dropped from 0.33 to 0.192.

Drainage area for each sub-basin was determined based on terrain DEM, with automated basin delineations performed in WISE. Basin break points were set by the user with a sub-basin target of one square mile in size. This criterion was adjusted for streams with larger drainage areas in order to avoid excessive and unnecessary discharge breaks. Break points were also set just upstream of stream confluences. Cumulative drainage area was determined based on these automated delineations performed by WISE in combination with a stream connectivity routine that defined the stream reach segments with upstream and downstream neighbors.

In a previous BLE study in the neighboring Guadalupe-Blanco watershed, an adjustment factor was applied to regression discharges. The adjustment factor was developed by comparing gage analysis on 19 gages throughout the watershed to the computed regression discharges. A detailed explanation of the development of the adjustment factors can be found in the FEMA Region 6 BLE report "Middle Guadalupe HUC-8 Subshed, TX, Base Level Engineering (BLE) Results".

Gage data was reviewed to determine if a similar adjustment factor should be applied to the Medina Watershed. A gage analysis was performed on three gages with peak stream flow records in the Medina Watershed. Figure 3 shows the location of the three gages used while Table 1 lists the gages. Initial testing showed the same tendency for the regression analysis to under-predict flood discharges as was noted in the previous BLE study. The results of the Medina gage analyses were added to the results from the Guadalupe-Blanco discharges to test whether or not they showed a need for a change in the adjustment factor for Medina. It was determined that the additional gage data had minimal effect on the overall adjustment factor. For consistency, the original adjustment factors from the Guadalupe-Blanco watershed BLE study were applied, unchanged, to the Medina regression equation results. Final discharges used for BLE study streams reflect the results from the regression analysis multiplied by the factors. Both the regression equations and adjustment factors used are shown in Table 2, below.

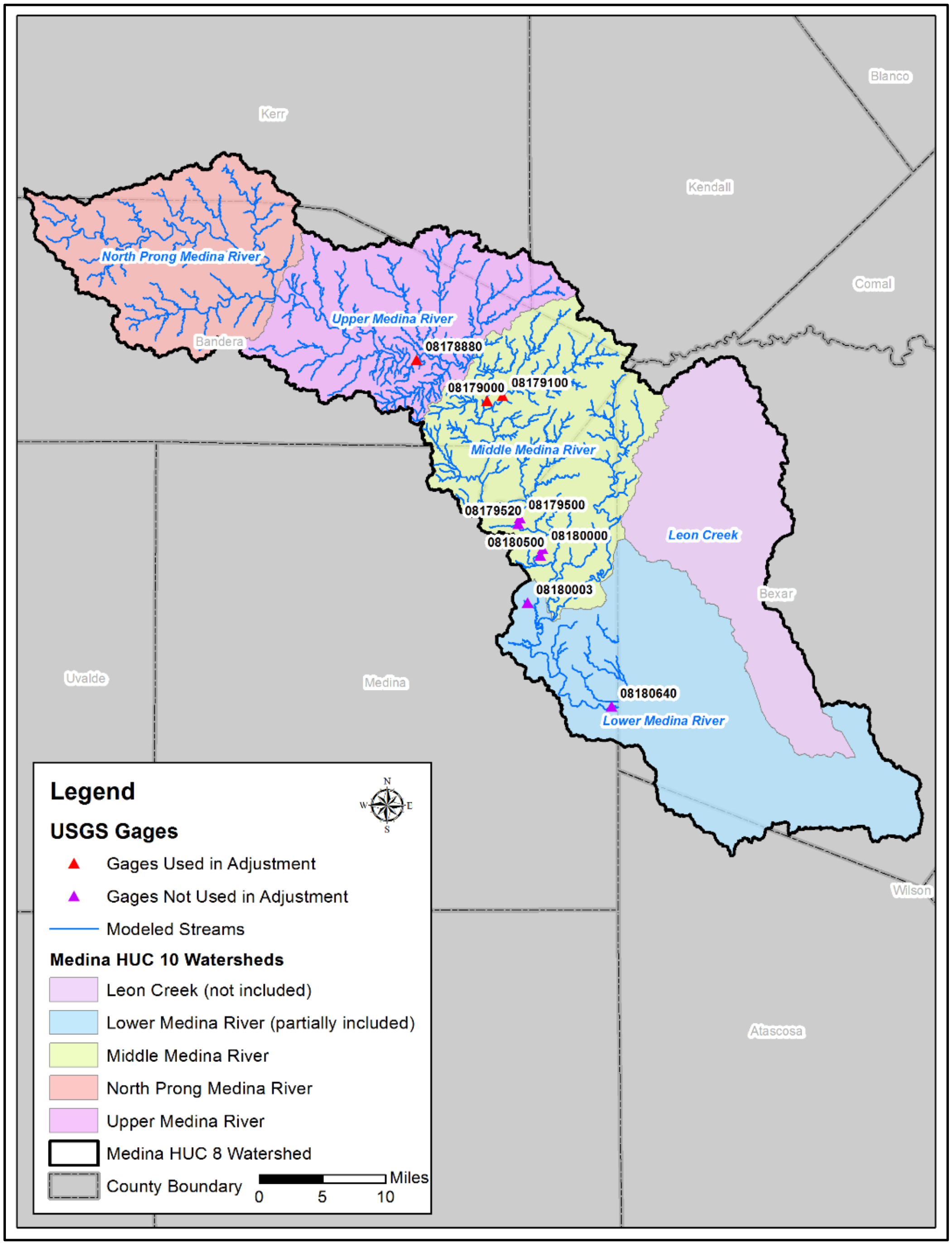

Figure 3: Locations of USGS Gages Utilized in Adjustment Calculation

Table 1: USGS Stream Gages in Study Area

Gage ID	Flooding Source and Location	Published Drainage Area (mi.^{2})	Period of Record
08178880	Medina River at Bandera, TX	328	1983-2018
08179000	Medina River near Pipe Creek, TX	474	1923-1981
08179100	Red Bluff near Pipe Creek, TX	56.3	1957-1981

Table 2: Summary of Regression Equations with Medina Adjustment Factor (SIR 2009-5087)

Recurrence Interval	Equation	Medina Multiplier
$Q_{10\%}$	$P^{1.203} \times S^{0.403} \times 10^{[0.918\Omega + 13.62 - 11.97A^{\wedge}(-0.0289)]}$	1.121
$Q_{4\%}$	$P^{1.140} \times S^{0.446} \times 10^{[0.945\Omega + 11.79 - 9.819A^{\wedge}(-0.0374)]}$	1.321
$Q_{2\%}$	$P^{1.105} \times S^{0.476} \times 10^{[0.961\Omega + 11.17 - 8.997A^{\wedge}(-0.0424)]}$	1.454
$Q_{1\%}$	$P^{1.071} \times S^{0.507} \times 10^{[0.969\Omega + 10.82 - 8.448A^{\wedge}(-0.0467)]}$	1.564
$Q_{0.2\%}$	$P^{0.988} \times S^{0.569} \times 10^{[0.976\Omega + 10.40 - 7.605A^{\wedge}(-0.0554)]}$	1.789
Variables: Q_i, peak flow for i recurrence interval (a.c.e.), in cubic feet per second; P, mean annual precipitation, in inches; S, Main-channel slope (dimensionless); Ω, OmegaEM parameter; A, cumulative drainage area, in square miles		

Discharges for the 1-percent plus and 1-percent minus a.c.e. were calculated as well. These values were computed as $Q_{1\%+/-} = Q_{1\%} \pm 10^{1.6*0.30}$, where 0.30 is the mean residual standard error for the $Q_{1\%}$ equation.

1.3 Hydraulics

The hydraulic approach for this BLE analysis of the Medina Watershed consisted of using the terrain model described in Section 1.1 in combination with the hydrologic outputs from Section 1.2 to establish water surface elevations using 1-D steady state analysis. HEC-RAS program version 4.1.0 was chosen as the computer model to compute water surface elevations on a stream by stream basis. The WISE software was used to establish model stream orientation, generate initial hydraulic cross section layout and stationing, assign n-values to cross-sections, and develop all input files for the HEC-RAS program. ESRI's ArcGIS program was used to review and refine cross-section layout orientation.

First pass cross-section layout was performed using an automated routine in WISE that varies cross-section spacing based on the cumulative drainage area at the cross-section location. A first draft model was created based on this initial cross-section layout, and draft boundaries were developed. Next, a second pass inspection for cross-section placement and alignment occurred. Significant refinement occurred during this step. To improve the hydraulic models, additional cross-sections were added as needed to better define the BLE floodplain boundary. Cross-sections were extended in locations where overtopping occurred. Orientation of cross-sections was refined to improve on the perpendicular orientation to flow. Additional cross-sections were added at floodplain constrictions and at downstream portions of tributaries to ensure a proper tie-in with receiving streams. Cross-sections were adjusted to remove sections that intersected hydraulic crossings in the floodplain. For some of the largest studied streams, cross-sections were laid out manually in order to have more reasonable spacing and better capture the constrictions in the floodplain.

Cross-sections were not drawn on top of roadways or railroads but were placed at the upstream and downstream face of major roads and railroads. Ineffective flow stations were placed in the hydraulic models as appropriate to account for flow constrictions and other locations deemed by the engineer to be ineffective at conveying flow downstream.

Cross sections were drawn on dam crests for significant dams with well defined spillways in order to better represent ponded water upstream of the structures. In so doing, it was assumed that the vast majority of the flow during a flood event would pass the spillway and that the hydraulic model would reasonably estimate flow across the spillway as represented in the hydraulic cross section. This was the method used for the Medina Dam Lake as flood elevations at the desired frequencies were not available, except for in the effective Bandera County FIS, where the dates of analysis were deemed too limited to be reliable, particularly since they did not include the July 2002 storm. Instead, the elevations used in the modeling were checked against known elevations during that July 2002 flooding event, as well as against effective Zone A boundaries, and the results were determined reasonable.

The relationship between cumulative drainage area and assigned channel geometry is shown in Table 3. These default values for dimensions and spacing were subject to change based on engineering judgment.

Table 3: Cross-Section Default Parameters

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
1	500	4	3.5	0.5
2	500	6	5	0.5
4	500	11	10	0.5
8	500	18	17	0.5
10	500	20	19	0.5
15	500	26	25	0.5
20	500	32	31	0.5
25	500	38	36	0.5
30	500	43	41	0.5
40	500	52	50	0.5
50	600	60	57	1
75	600	68	65	1
100	750	76	73	1
150	750	91	88	1
250	1000	122	119	2

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
500	1500	198	195	3
1000	2500	351	346	3

In typical BLE projects, Manning's roughness coefficients (n-values) are determined using the 2011 National Land Cover Data (NLCD) dataset in combination with n-values from Chow (1959) and Calenda et al. (2005). For this watershed, the n-values for the developed areas indicated an underestimation of the roughness coefficients when compared to the aerial imagery and were adjusted accordingly. The association between the n-values and the NLCD Classification is shown in Table 4. Manning's n-value takeoffs are performed by WISE (default values taken from the "Normal" column). N-values within channel banks are constrained by the automated routine to a range of 0.030 to 0.070. Then, overbank and channel n-values are manually adjusted in certain locations based on engineering judgment.

Table 4: Manning's "n" Roughness Based on 2011 NLCD Classification (Moore, 2011)

NLCD Classification	Selected Manning's n	Minimum	Normal	Maximum	Source
Open Water	0.033	0.025	0.03	0.033	Chow 1959
Developed, Open Space	0.035	0.01	0.013	0.016	Calenda et al. 2005
Developed, Low Intensity	0.063	0.038	0.05	0.063	Calenda et al. 2005
Developed, Medium Intensity	0.094	0.056	0.075	0.094	Calenda et al. 2005
Developed, High Intensity	0.1	0.075	0.1	0.125	Calenda et al. 2005
Barren Land	0.035	0.025	0.03	0.035	Chow 1959
Deciduous Forest	0.1	0.1	0.12	0.16	Chow 1959
Evergreen Forest	0.1	0.1	0.12	0.16	Chow 1959
Mixed Forest	0.1	0.1	0.12	0.16	Chow 1959
Scrub/Shrub	0.07	0.035	0.05	0.1	Chow 1959
Grassland/Herbaceous	0.035	0.025	0.03	0.035	Chow 1959
Pasture/Hay	0.05	0.03	0.04	0.05	Chow 1959
Cultivated Crops	0.045	0.025	0.035	0.045	Chow 1959
Woody Wetlands	0.1	0.08	0.1	0.12	Chow 1959
Emergent Herbaceous Wetland	0.1	0.07	0.1	0.15	Chow 1959

The downstream boundary condition used for the majority of the study streams was normal depth with a default value of 0.005 ft/ft. For streams with large drainage areas (generally greater than eight square miles), the normal depth slope was calculated based on the channel inverts of the downstream cross sections.

1.4 Quality Control

Following the initial hydraulic model analysis in each watershed, the resulting flood hazard area delineations were reviewed for areas where the results were not ideal.

QC results indicated that some of the models should be extended to cover the scope of effective flood hazard data. Those streams were extended farther upstream to match the extents of the effective SFHA data.

Typical revisions resulting from reasonability checks included adding cross-sections, adjusting orientation of cross-sections, trimming cross-sections and reduction of the default “V” angle of cross-sections. Examples of default “V” angled cross-sections are shown in Figure 4. It is estimated that 75 percent of cross-sections were adjusted in some work areas while other areas did not require as much editing. Other examples of manual editing included the addition of cross-sections at confluence areas (see Figure 5 below), modifications to improve perpendicular orientation at the channel, adjustment of discharge breaks to better represent flow addition points, revisions to cross sections at dams, additional cross-sections bounding major hydraulic structures, and revisions to n-values.

A major component of the QC process was an automated check that identified locations where the 1-percent a.c.e profile was crossed by any other frequency profile. Significant effort was made to reasonably resolve all of these instances. Another automated check identified locations where there was a drawdown of greater than 0.5 foot on the 1-percent a.c.e. water surface profile. This check is particularly useful for identifying errors in the model such as a channel that is too wide, a poorly placed cross-section, or a need for additional cross-sections. Again, significant effort was made to reasonably resolve these drawdown situations.

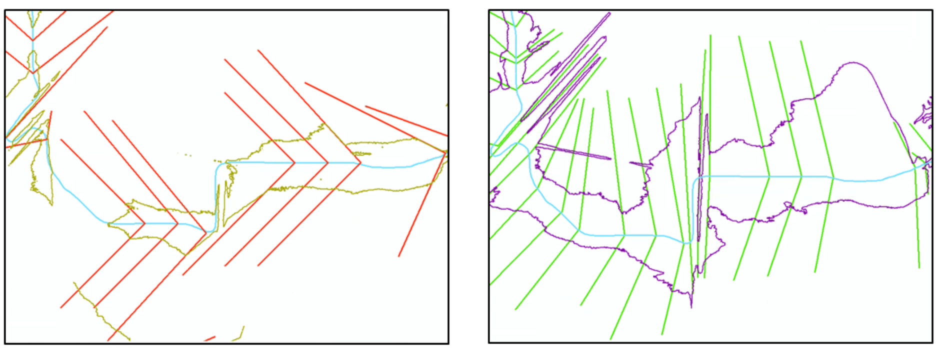

Figure 4: Default "V" angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.

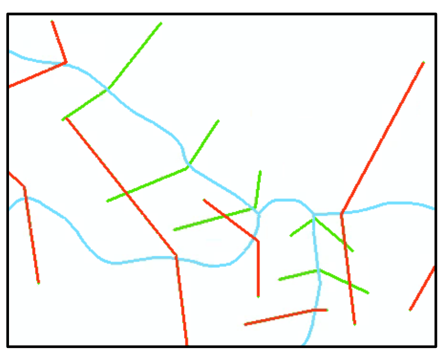

Figure 5: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

1.5 One-percent Special Flood Hazard Area Delineation

The 1-percent and 0.2-percent boundaries were mapped using a routine that develops water surface elevation grids based on the 10-foot cell size DEM developed from the LiDAR dataset used for this project (see Section 1.1). This product was converted to a polygon for cleaning. The cleaning routine involved manual inspection of the polygons to identify and remove areas of disconnected flooding. In general, all polygons greater than 5,000 square feet are investigated, but all polygons, including those less than 5,000 square feet that intersect the stream line are included in the final output. This investigation was aided by the ground DEM and aerial imagery. Manual adjustments to the polygons were made to account for spillways on dams which could not be accurately modeled using HEC-RAS as well as disconnected areas along the flooding source that should reasonably be connected.

Following the removal of disconnected flooding areas and other boundary adjustments, the small islands in the floodplain were filled. In general, islands less than 20,000 square feet were inspected and filled.

Once the island filling process was complete, the water surface raster mapping routine was run and set to conform to the polygon boundary. This ensures that the water surface raster and the floodplain boundary are consistent with each other. The depth raster product was created at the end of the process by performing a raster subtraction with the water surface elevation raster and the ground DEM.

Challenges

The Medina Watershed is located in Central Texas, an area known for flat terrain. In some of the wide and flat floodplains, small tributaries run parallel to large streams. Parallel streams with shared floodplains were modeled by moving the combined discharge upstream to the cross-section that begins the shared floodplain.

A significant effort was made to achieve proper 1% water surface elevation tie-ins at stream confluences. Cross-sections were manually added on the downstream end of nearly every stream, some of which traverse the receiving stream; so that the water surface elevation of the tributary would be lower than that of the receiving stream.

There are a significant number of dams of varying sizes throughout the watershed. Discharges calculated with the regression equations do not take into account the impact of these structures. There may be need for further investigation, particularly for those dams designed for flood control, when upgrading these models for detailed studies.

There are a few containment issues across the study area. In some areas, the 0.2% flows overtopped cross sections. For these situations, additional investigation is recommended when upgrading these models for detailed study.

Area-specific challenges follow:

In the North Prong Medina HUC-10 watershed, West Prong Medina River requires further study as cross-sections are overtopped. This is represented in the mapping and grids as an abrupt edge.

In the Upper Medina River HUC-10 watershed, multiple streams require further study as cross-sections are overtopped: San Julian Creek, Unnamed Tributary 046, Unnamed Tributary 074, Unnamed Tributary 083, Unnamed Tributary 084, Unnamed Tributary 086, and Unnamed Tributary 087a. This is represented in the mapping and grids as an abrupt edge.

In the Middle Medina River HUC-10 watershed, multiple streams require further study as cross-sections are overtopped: Bruins Creek, Medina River, Mesquite Creek, San Geronimo Creek, Unnamed Tributary 103, and Unnamed Tributary 121a. This is represented in the mapping and grids as an abrupt edge.

In the Lower Medina River HUC-10 watershed, multiple streams require further study as cross-sections are overtopped: Dry Branch, Kempf Creek, Little Sous Creek, Medina River, and Sherer Creek. This is represented in the mapping and grids as an abrupt edge.

Results and Recommendations

The BLE results for this study produced an SFHA that conforms to the existing topography and compares favorably with the effective SFHA. These boundaries provide an estimated SFHA in areas that have not been previously studied and therefore do not currently have an SFHA mapped. These results provide context for flood risk communication as part of the Discovery process, and should be verified through community work map meetings before being applied to a regulatory product.

A map showing the BLE results is included as Appendix A.

3.1 CNMS Validation of Effective Zone A SFHA

The inventory of Zone A studies assessed (73.1 miles) in the Medina Watershed were classified in CNMS with validation status of “UNVERIFIED” (70.3 miles) or “VALID” (2.8 miles), and with status type of “BEING STUDIED.” The following is a summary of the results of the CNMS validation assessment for the effective Zone A studies in the study area. Initial Assessment checks A1-A3 were evaluated for the CNMS inventory of Zone A studies; however, CNMS validation checks were not completed for streams that were included in the recent Physical Map Revision under FEMA Case No. 19-06-0043S.

INITIAL ASSESSMENT A1 – SIGNIFICANT TOPOGRAPHY UPDATE CHECK

This check involves determining whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. For the study area in the Medina Watershed except for a single reach modified by Letter of Map Revision (LOMR) in 2017, none of the effective studies utilized LiDAR data. The LiDAR sources discussed in section 1.1 are a significant improvement from the effective Zone A topographic source for the entire study area except for the single LOMR reach. Therefore, all reaches but the one LOMR reach failed this check for the effective SFHA.

INITIAL ASSESSMENT A2 – CHECK FOR SIGNIFICANT HYDROLOGY CHANGES

This check involves first determining if regression equations were used for the effective study. Next, it must be determined whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent annual chance flow.

Regression equations were not used for the effective hydrologic analyses for any effective Zone A study areas located in the Medina watershed and, therefore, pass this assessment check.

INITIAL ASSESSMENT A3 – CHECK FOR SIGNIFICANT DEVELOPMENT

This check involves using the National Urban Change Indicator (NUCI) dataset to assess increased urbanization in the watershed of the Zone A study. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15% or more, and has increased by 50% or more since the effective analysis, the study would fail this check. Although the NUCI data provide year-to-year changes in urbanization, the NLCD also is needed to establish a baseline of urban land cover for this analysis. The check for significant development in this watershed was completed by evaluating percentage of urban change at the HUC-12 level. The entire study area is still classified as rural, so all reaches pass this check.

All of the initial assessment results are shown in Table 5.

Table 5: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Pass/Fail	LiDAR was used for effective study/LiDAR sources available are a significant improvement from effective topography
A2 – Hydrology	Pass	Regression equations not used in effective study
A3 – Development	Pass	HUC-12 watershed does not meet urban threshold

VALIDATION CHECK A4 – CHECK OF STUDIES BACKED BY TECHNICAL DATA

Zone A studies that pass all initial assessment checks described above may be categorized as "Valid" in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A's is performed. Zone A studies in Bandera and Bexar Counties are not backed by technical data and, therefore, fail this check. All Zone A studies within Medina County are model-backed studies and pass this check.

VALIDATION CHECK A5 – COMPARISON OF BLE AND EFFECTIVE ZONE A

The BLE /effective Zone A comparison method leverages the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA SID 113, but with a slight modification. This modified FBS comparison approach uses the 1-percent plus and 1-percent minus flood profiles and horizontal and vertical tolerances described in FEMA's Automated Engineering guidance document dated May 2016. For the comparison of BLE and effective Zone A in the Medina Texas study area, the following vertical and horizontal tolerances were used to conduct the modified FBS procedure. One point was placed every 200 feet along the floodplain boundaries for comparison.

- Vertical Tolerance: +/- 10 feet (one-half contour interval of assumed effective topographic source).
- Horizontal Tolerance: +/- 75 feet (standard horizontal tolerance for BLE comparison testing).

Comparison results for these streams were grouped at the HUC-12 level and are summarized in Table 6 to better understand the general health of the HUC-12 watershed, but the validation check was performed at the stream level. Streams where the percentage of passing FBS sample points is greater than or equal to 85% are marked as "Pass", otherwise they are marked as "Fail".

Table 6: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Medina Watershed	All Streams	4,352	1,692	2,660	61%	FAIL	
Big Sous Creek	12100302050	763	193	570	75%	FAIL	18.4
Diversion Lake-Medina River	12100302030	26	19	7	27%	FAIL	58.5
Flat Creek-Medina River	12100302050	101	23	78	77%	FAIL	18.2
Lower San Geronimo Creek	12100302030	1,781	908	873	49%	FAIL	41.6
Upper San Geronimo Creek	12100302030	1,681	549	1,132	67%	FAIL	27.8

VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Medina Watershed has been updated as summarized in Table 7 and illustrated in Figure 6 below.

Table 7: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	2.8
UNVERIFIED	BEING STUDIED	70.3

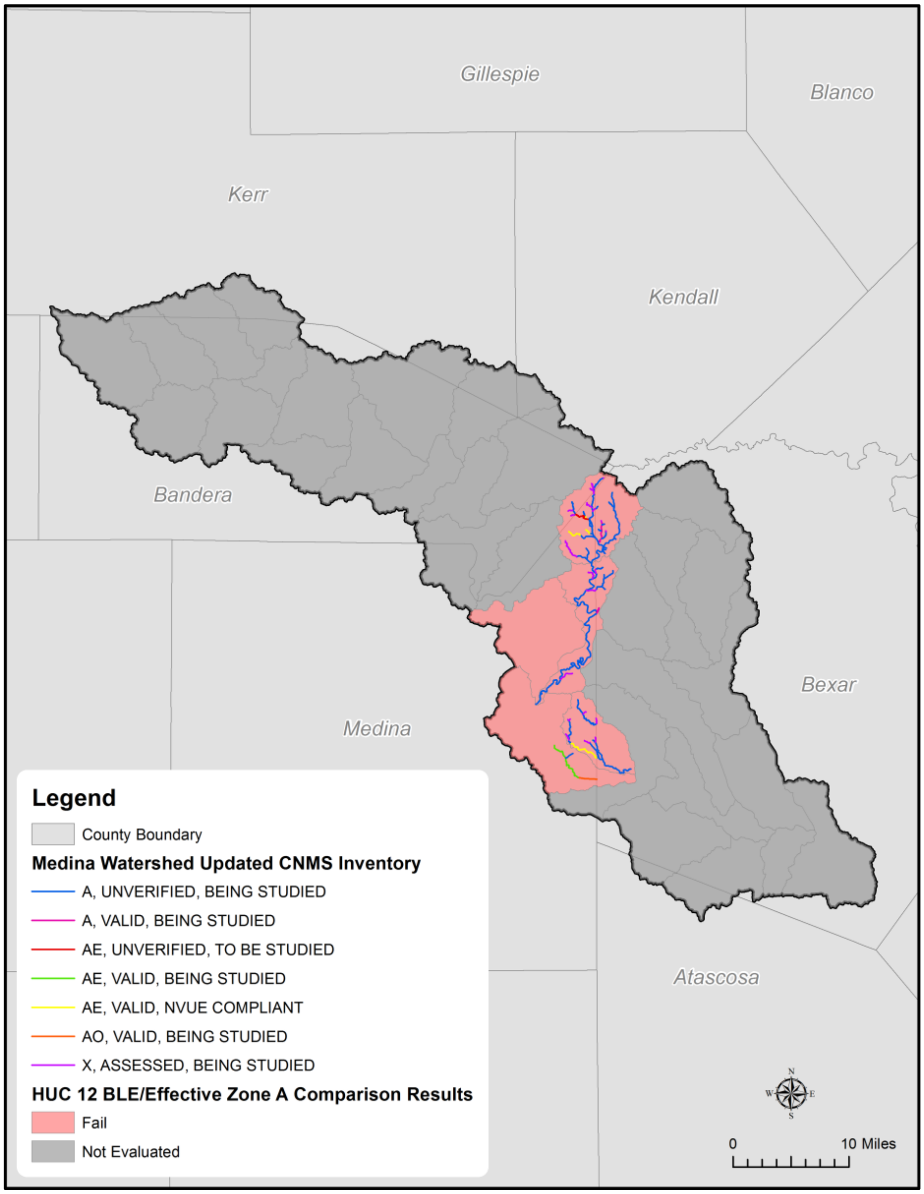

Figure 6: Medina Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effective to determine the priority score. Figure 7 below shows the range of the HUC-12 priority scores which can be used to initiate discussions during the Discovery phase.

Diversion Lake-Medina River HUC-12 was determined to have the highest priority score and the most need while Flat Creek-Medina River HUC-12 had the lowest score.

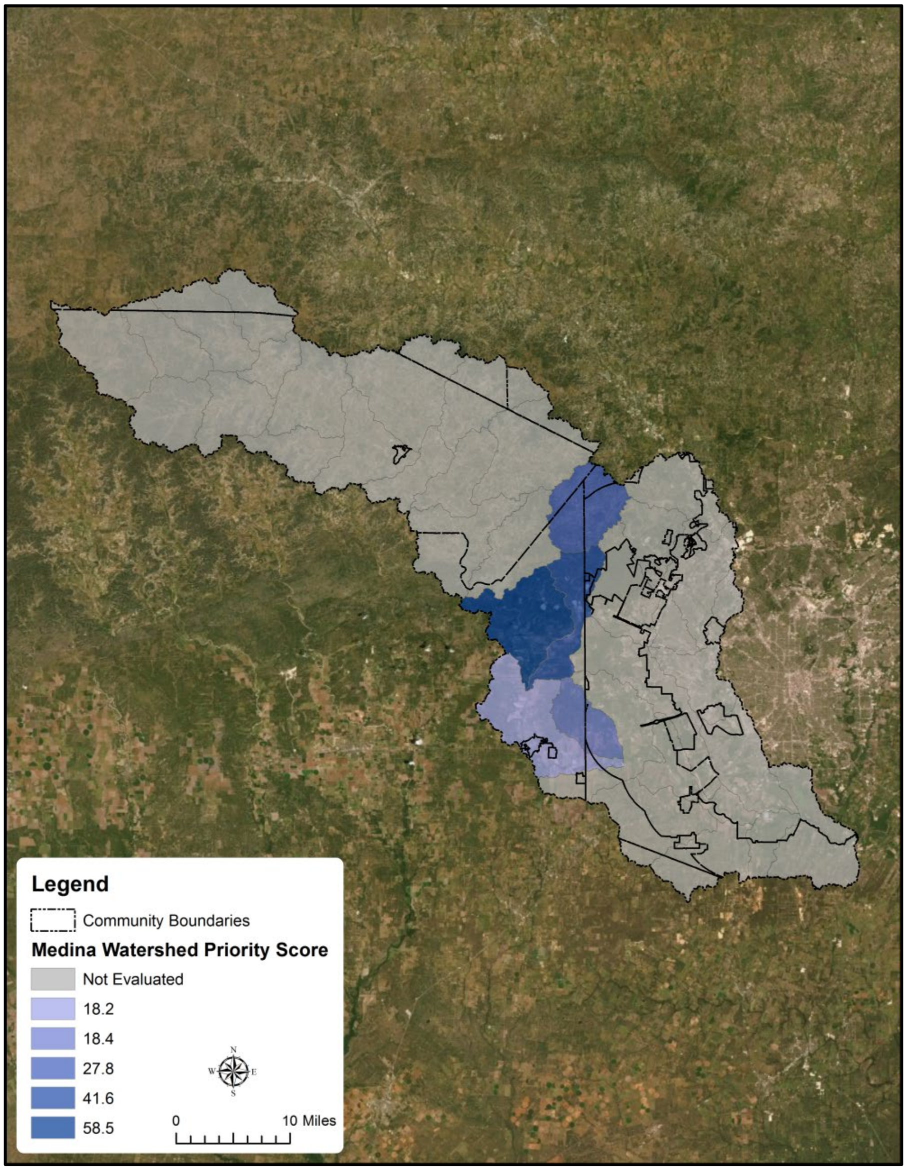

Figure 7: Ranking of Medina Watershed HUC-12s

3.2 Flood Risk Analysis

An advanced flood risk analysis was performed using the updated 1-percent-annual-chance grid (known as ‘refined base level engineering grid”) created for this project. The loss analysis uses 2010 census data and the subsequent results are stored in the L_RA_Results table.

Hazus version 4.2 was used for the loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 4.2 uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by other bodies of water, wetlands, or forests) from the Census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA’s Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

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Appendix A BLE Map